

# STORAGE QUALITY OF ETHYLENE TREATED 'ANJOU' AND 'BOSC' WINTER PEARS

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## ABSTRACT

*'Anjou' and 'Bosc' pears (Pyrus communis, L.) were harvested one to two days prior to commercial harvest from three orchards in the Wenatchee growing district of Washington. Harvested fruit were treated with 300 ppm ethylene for three days at 20C. Ethylene treatment enhanced yellow color on fruit peel and the reduction of flesh firmness, and increased spoilage after 90 days in either regular atmosphere (RA) storage or controlled atmosphere (CA) storage regardless of cultivar. Ethylene-treated fruit, of both cultivars, stored in CA had a longer storage life than fruit stored in RA. The safe storage period of ethylene-treated 'Anjou' and 'Bosc' pears was 90 and 45 days, respectively, in RA and 120 and 90 days, respectively, in CA.*

## INTRODUCTION

Increased 'Anjou' and 'Bosc' winter pear (*Pyrus communis*, L.) production has forced the pear industry in the Pacific Northwest to evaluate the possibility of marketing fruit earlier. Marketing winter pears immediately after harvest has not been recommended in the past due to a period of chilling required to induce normal

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ripening (Blankenship and Richardson 1985; Knee 1987; Lebond and Ulrich 1973; Morin *et al.* 1985). Previous studies with 'Anjou' and 'Bosc' pears have shown that fruit harvested at commercial maturity require a storage period of 45 to 60 days at  $\pm 1^{\circ}\text{C}$  to be able to ripen normally (Chen and Mellenthin 1981; Eeden *et al.* 1991). A more recent study (Kupferman 1994) showed that commercially packed winter pears shipped before November would not ripen properly during 7 days at room temperature. To alleviate the nonripening problem, early in the market season, a study was conducted that showed winter pears could be preconditioned with ethylene and ripen normally without a cold storage treatment (Hansen and Blanpied 1968; Chen *et al.* 1996).

However, it is unknown how long ethylene treated winter pears can be stored before ripening is initiated and is quality lost. The objective of this study was to initiate ripening of winter pears immediately after harvest by exposure to ethylene and determine storage-life in regular and controlled atmosphere.

## MATERIALS AND METHODS

'Anjou' and 'Bosc' pears were harvested in 1997 and 1998 one to two days prior to commercial harvest, at a flesh firmness of 66N, from three orchards in the Wenatchee, WA growing district. One to two days after harvest, six boxes (80 pears/box) of 'Anjou' and 'Bosc' pears from each orchard were treated for 3 days at 20C in a room containing 300 ppm ethylene using an Easy-Ripe Ethylene Generator (Catalytic Generators Inc., Norfolk, VA). Nonethylene treated controls were kept for 3 days at 20C. Treated and nontreated fruit were each divided into 2 groups and placed in RA storage at 1C, or CA storage (1.5% O<sub>2</sub> and < 1.0% CO<sub>2</sub>) at 1C using a computer controlled purge type CA system (Technical Consulting Services, Chelan, WA). Pears were stored for 45 and 90 days in RA, and 90, 120 and 180 days prior to quality evaluation. After each storage period, 20 pears were removed from each cultivar, treatment and location. Ten pears were evaluated immediately upon removal from storage and ten evaluated after an additional 7 days at 20C.

Firmness was determined using the TA-XT2, Texture Analyzer (Texture Technologies, Scarsdale, NY) equipped with a 7.7 mm probe. Soluble solids content (SSC) and titratable acidity (TA) were determined from an aliquot of expressed juice of a longitudinal slice from each of 10 pears. An Abbe type refractometer with a sucrose scale calibrated at 20C was used to determine SSC. TA was measured with a Radiometer titrator, model TTT85 (Radiometer, Copenhagen, Sweden). Acids were titrated to pH 8.2 with 0.1 N NaOH and expressed as percent malic acid. External and internal color was determined with The Color Machine (Pacific Scientific, Silver Springs, MD) using the Hunter L\*, a\*, b\* system and calculated hue values (Hunter and Harold 1987). Finish, scald,

shrivel, stem condition and pithy brown core were determined by 2 individuals familiar with winter pear disorders and graded on a scale of 1 to 4 (1 = excellent/none; 4 = poor/severe). Data was analyzed using MSTAT-C (1988) as a factorial design (years combined) using ethylene treatments as the main plot and storage time and ripening as the subplots with orchards used as replication. Pears in RA and CA storage were analyzed separately. Based on significant F test means were separated using Tukey's (HSDT).

## RESULTS AND DISCUSSION

### 'Anjou'

After ethylene treatment, pears were lighter (higher  $L^*$  values), less green (lower  $a^*$  values), and more yellow (higher  $b^*$  values) than nontreated pears (Table 1). This external color difference was easily visible as evident by hue values for external color. Difference in external hue between ethylene treated and nontreated pears ranged from 3 to 7 units for pears from CA and RA storage, respectively. A difference of 1 hue unit can be perceived by human vision (Hunter and Harold 1987).

Internal color of 'Anjou' pears was also influenced by ethylene treatment, but not to the same degree as that of external color. There was no difference in  $L^*$  value, but the internal color of ethylene-treated pears was less green and more yellow than nontreated pears regardless of storage. Internal hue values indicated a more yellow flesh color in ethylene-treated pears, but the difference was only 1.1 units for pears from RA storage and < than 1 for pears from CA storage and therefore might not be detected by the consumer.

Compared with the 45 days storage, pears held for 90 days were less green and more yellow resulting in smaller hue values. RA storage had little influence on internal color of 'Anjou' pears ( $b^* = 0.7$ ) and no effect if hue values were considered. In CA storage there was a greater change in external color from 90 to 120 than there was between 120 and 180 days. In addition, as storage time (CA) increased pears became less green and more yellow. The change in internal color (except for  $L^*$  values) of pears from CA storage was not systematic and not considered to be of consequence.

Pears ripened for 7 days at 20C were more yellow than prior to ripening and this was noted regardless of storage type (RA and CA). Ripening also resulted in changes in internal color of 'Anjou' pears, but only the differences in hue of pears from RA storage was large enough to be visible by the consumer.

Firmness of ethylene treated pears decreased after both 45 and 90 days of RA storage, whereas nontreated pears did not (Table 2). Firmness loss for ethylene-treated pears would be a potential problem during both shipping and

TABLE 1.  
EXTERNAL AND INTERNAL HUNTER COLOR OF 'ANJOU' PEARS AFTER ETHYLENE  
EXPOSURE, REGULAR OR CONTROLLED ATMOSPHERE STORAGE AND RIPENING

Treatment	L*	External Color			L*	Internal Color		
		a*	b*	hue		a*	b*	hue
Regular Atmosphere (RA) Storage								
Ethylene								
No	64.6b	-5.1b	26.7b	102.3a	78.4a	0.9b	17.3b	87.0a
Yes	69.6a	-2.8a	29.3a	95.7b	78.7a	1.3a	17.8a	85.9b
Storage time (days)								
45	67.3a	-5.1b	27.1b	101.0a	78.5a	1.1a	17.2b	86.4a
90	66.8a	-3.4a	28.9a	97.0b	78.7a	1.1a	17.9a	86.5a
Ripening time (days)								
0	64.4b	-5.5b	26.1b	102.1a	79.6a	0.9b	17.3b	87.1a
7	69.8a	-2.9a	29.9a	95.8b	77.5b	1.3a	17.8a	85.8b
Controlled Atmosphere (CA) Storage								
Ethylene								
No	62.2b	-6.3b	26.2a	103.7a	77.3a	0.7b	18.0b	87.7a
Yes	64.7a	-5.1a	28.0b	100.4b	77.8a	1.0a	18.5a	87.0b
Storage time (days)								
90	63.1a	-6.0c	26.3b	103.0a	79.4a	0.7b	17.5b	87.7a
120	63.6a	-5.7b	27.7a	101.9b	76.5b	1.1a	18.8a	86.8b
180	63.6a	-5.4a	27.3a	101.4b	76.8b	0.7b	18.4a	87.6a
Ripening time (days)								
0	61.1b	-6.7b	25.0b	105.1a	77.6a	0.7b	18.0b	88.0a
7	65.8a	-4.6a	29.2a	99.1b	77.5a	1.1a	18.5a	86.7b

<sup>a</sup>Means in a column, within treatments, not followed by a common letter are significantly different ( $P > 0.05$ )

TABLE 2.  
QUALITY OF 'ANJOU' PEARS AFTER ETHYLENE EXPOSURE AND REGULAR  
ATMOSPHERE (RA) STORAGE AS INFLUENCED BY TIME IN STORAGE AND 7 DAYS OF  
RIPENING

Treatment		Firmness (N)	Fruit Finish (1 to 4) <sup>y</sup>	Scald (1 to 4)	Shrivel (1 to 4)	Stem Condition (1 to 4)
<b>Ethylene x Time in Storage</b>						
No	45	36.3a <sup>z</sup>	1.0c	1.0b	1.0a	1.0c
	90	34.2a	1.5b	1.1b	1.0a	1.6a
Yes	45	24.6b	1.0c	1.0b	1.0a	1.0c
	90	20.5c	2.0a	2.0a	1.0a	1.4b
<b>Ethylene x Ripening</b>						
No	0	61.1a	1.5b	1.0b	1.0a	1.0c
	7	9.4c	1.6b	1.1b	1.0a	1.6a
Yes	0	37.2b	1.5b	1.0b	1.0a	1.0c
	7	7.9c	2.8a	2.0a	1.0a	1.3b

<sup>z</sup>Means in a column, within treatments, not followed by a common letter are significantly different ( $P \geq 0.05$ )

<sup>y</sup>Graded on a scale of 1 to 4 (1 = excellent/none and 4 = poor/severe).

marketing when pears tend to lose firmness very rapidly. This ethylene-treated fruit would have to be handled carefully to maintain even minimal quality. Quality loss for ethylene treated pears is amplified after 90 days when scald increased and fruit finish and stem condition deteriorated. The loss of fruit finish and the increased scald after 90 days were also evident for nontreated pears, but not to the extent as was seen on ethylene treated pears. After the same storage time nontreated pears displayed poorer stem condition than treated pears, but stem scores were considered acceptable for both treated and nontreated pears (a score of 2 or less).

Before ripening, nontreated pears were firmer than ethylene treated pears, but after seven days of ripening firmness was similar. Although scores for fruit finish and scald were identical between treatments before ripening, fruit finish decreased and scald increased, for ethylene-treated pears after ripening. Stem condition was similar between treated and nontreated pears prior to ripening, but declined after ripening in treated pears (Table 2). Considering both RA storage and ripening ethylene-treated pears should be marketed before nontreated pears and stored for a time not to exceed 90 days to ensure the best quality fruit.

Firmness of 'Anjou' pears, in CA, decreased regardless of storage period (Table. 3). Ethylene treated pears lost firmness at a more rapid pace than nontreated pears especially after 120 days of CA storage. At 90, 120 and 180 day storage nontreated pears were firmer than treated pears. For nontreated pears, firmness

TABLE 3.  
QUALITY OF 'ANJOU' PEARS AFTER ETHYLENE EXPOSURE AND CONTROLLED  
ATMOSPHERE (CA) STORAGE AS INFLUENCED BY TIME IN STORAGE AND 7 DAYS OF  
RIPENING

Treatment		Firmness (N)	Fruit Finish (1 to 4) <sup>y</sup>	Scald (1 to 4)	Shrivel (1 to 4)	Stem Condition (1 to 4)
<b>Ethylene x Time in Storage</b>						
No	90	40.9b <sup>z</sup>	1.0d	1.0c	1.0c	1.1c
	120	43.8a	1.5cd	1.5b	1.9b	1.2c
	180	36.2c	2.0c	1.1c	2.2a	1.2c
Yes	90	32.8d	2.0c	1.0b	1.0c	1.4c
	120	32.2de	2.5b	2.0a	2.3a	1.6b
	180	19.6e	2.7a	1.5b	2.3a	2.1a
<b>Ethylene x Ripening</b>						
No	0	64.6a	1.0b	1.0b	1.6a	1.0c
	7	16.0c	1.2b	1.5b	1.8a	1.3b
Yes	0	52.3b	1.2b	1.0b	1.9a	1.4b
	7	10.8d	1.7a	2.0a	1.9a	2.0a

<sup>z</sup>Means in a column, within treatments, not followed by a common letter are significantly different ( $P > 0.05$ )

<sup>y</sup>Graded on a scale of 1 to 4 (1 = excellent/none and 4 = poor/severe).

after 180 days was still greater than for treated pears after 90 days. Firmness of nontreated pears was greater than that of treated pears, both immediately after 90, 120, or 180 days of storage and after 7 days of ripening.

Fruit finish steadily decreased as time of storage progressed, but that of ethylene treated fruit declined more rapidly than that of nontreated fruit. Finish score for nontreated fruit was 2.0 after 180 days of CA storage, whereas that for treated fruit was 2.0 after only 90 days of CA and increased to 2.7 after 180 days of storage. Finish scores were similar between nontreated fruit immediately after storage and after 7 days of ripening, and treated fruit immediately after storage. Finish score for treated fruit after 7 days of ripening further increased. Scores for shrivel between treatments were similar after 90 of storage. Ethylene-treated pears shriveled more rapidly than nontreated pears between 90 and 120 days, but at 180 days shrivel scores were constant between treatments. The pattern for scald development, between treatments, was apparent during 7 days of ripening. Ethylene-treated fruit developed scald, while nontreated pears developed practically no scald.

Stem condition of ethylene-treated pears declined steadily during CA storage, whereas it remained constant for nontreated pears. After ripening stem condition score decreased in both treatments, but was worse for treated pears than nontreated pears.

**'Bosc'**

External color scores ( $L^*$ ,  $a^*$ ,  $b^*$ ) and hue increased in ethylene treated 'Bosc' pears, during RA storage, compared to treated pears (Table 4). There was some change ( $b^*$  and hue) in the color of treated 'Bosc' pears after CA storage compared to nontreated pears, but they were not as distinct as after RA storage. In both RA and CA storage ethylene treated pears were lighter in color with more red and yellow color and lower hue values indicating a riper colored pear, but the increased yellow color was only evident in pears from RA storage. There were noticeable differences in internal hue values only for pears from CA storage. As time in storage increased in both RA and CA storage pears developed more external red and yellow color and had lower hue values.

TABLE 4.  
EXTERNAL AND INTERNAL HUNTER COLOR OF 'BOSC' PEARS AFTER ETHYLENE EXPOSURE, REGULAR AND CONTROLLED ATMOSPHERE STORAGE AND RIPENING

Treatment	External Color				Internal Color			
	L	a	b	hue	L	a	b	hue
<b>Regular Atmosphere (RA) Storage</b>								
<b>Ethylene</b>								
No	54.4b	8.6b	21.6b	69.3a	78.6b	0.1a	17.7a	89.6a
Yes	56.6a	11.4a	23.2a	64.4b	79.0a	0.4a	17.4b	88.7a
<b>Storage time (days)</b>								
45	56.5a	9.7b	22.4a	67.9a	78.5b	0.4a	17.5a	88.6a
90	54.6b	10.3a	22.2a	65.7b	79.1a	0.1a	17.7a	89.7a
<b>Ripening time (days)</b>								
0	53.4b	6.8b	20.9b	72.5a	79.4a	-0.1b	17.7a	90.2a
7	57.7a	13.2a	23.9a	61.2b	78.5b	0.6a	17.4b	88.1b
<b>Controlled Atmosphere (CA) Storage</b>								
<b>Ethylene</b>								
No	52.4a	8.5b	21.2a	69.4a	77.1b	-0.5b	18.2a	91.5b
Yes	53.3a	9.8a	21.7a	66.4b	77.8a	0.1a	17.8a	97.5a
<b>Storage time (days)</b>								
90	53.8a	7.3b	19.9c	70.8a	79.2a	-1.1b	17.5a	103.7a
120	52.6b	9.6a	22.7a	67.9b	76.4b	0.1a	18.8a	89.6b
180	52.3b	10.5a	21.8b	65.4c	76.5b	0.1a	17.6a	80.5b
<b>Ripening time (days)</b>								
0	50.7b	5.8b	19.3b	73.6a	77.3a	-0.5b	17.7a	91.8b
7	55.1a	12.5a	23.7a	62.2b	77.5a	0.1a	18.2a	97.4a

<sup>a</sup>Means in a column, within treatments, not followed by a common letter are significantly different ( $P \geq 0.05$ )

TABLE 5.  
QUALITY OF 'BOSC' PEARS AFTER ETHYLENE EXPOSURE AND REGULAR  
ATMOSPHERE (RA) STORAGE AS INFLUENCED TIME IN STORAGE AND 7 DAYS OF  
RIPENING

Treatment		Firmness (N)	Fruit Finish (1 to 4) <sup>y</sup>	Internal Breakdown (1 to 4)	Rots (%)	Stem Condition (1 to 4)
<b>Ethylene x Time in Storage</b>						
No	45	36.8a <sup>z</sup>	1.0a	1.0b	0.0b	1.0c
	90	35.6a	2.3b	1.0b	2.0b	2.0b
Yes	45	20.6b	1.0a	1.0b	0.0b	1.0c
	90	15.1c	2.6b	2.0a	10.0a	2.5ab
<b>Ethylene x Ripening</b>						
No	0	57.3a	1.6a	1.0b	0.0b	1.0c
	7	15.2c	1.7a	1.1b	2.0b	2.0a
Yes	0	30.2b	1.6a	1.0b	0.0b	1.5b
	7	5.5d	2.0b	2.0a	10.0a	2.2a

<sup>z</sup>Means in a column, within treatments, not followed by a common letter are significantly different ( $P > 0.05$ )

<sup>y</sup>Graded on a scale of 1 to 4 (1 = excellent/none and 4 = poor/severe).

Firmness of nontreated pears was not affected by RA storage. But, ethylene-treated pears were softer than nontreated pears after 45 and 90 days (Table 5). Pear firmness prior to and after ripening was reduced for ethylene-treated versus nontreated pears. Fruit finish and stem condition were similar for treated and nontreated pears after 45 and 90 days of RA storage. Finish score of treated fruit after ripening was lower than nontreated fruit. Before ripening nontreated pears had better stem condition than treated pears; however there was no difference after ripening. Shrivel was present in both ethylene-treated and nontreated pears and shrivel scores were similar between treated and nontreated after each storage period.

Internal breakdown and the number of rotted fruit increased in ethylene-treated 'Bosc' pears after 90 days of storage. Internal breakdown, or rot of nontreated pears was not affected by storage or ripening period. Rot incidence of ethylene-treated pears was 10% after 90 days of storage, and after 7 days of ripening. This amount of rot would be unacceptable and not economically viable to both producer and consumer.

Firmness of 'Bosc' pears was similar after 90 and 150 days of CA storage regardless of ethylene treatment (Table 6) although after 120 days of storage ethylene-treated pears were softer than nontreated pears. Prior to ripening,



nontreated pears were 5.7 N firmer than treated pears, but after 7 days of ripening, values were similar (18.6 vs 15.6N, respectively). There was a reduction in fruit finish after 120 and 150 days of CA storage for treated pears compared to nontreated pears. Fruit finish was better for nontreated pears before and after ripening. Stem condition was deteriorated by ethylene treatment for all storage periods and during ripening.

TABLE 6.  
QUALITY OF 'BOSC' PEARS AFTER ETHYLENE EXPOSURE AND CONTROLLED  
ATMOSPHERE (CA) STORAGE AS INFLUENCED BY TIME IN STORAGE AND 7 DAYS OF  
RIPENING

Treatment		Firmness (N)	Fruit Finish (1 to 4) <sup>a</sup>	Shrivel (1 to 4)	Stem Condition (1 to 4)
<b>Ethylene x Time in Storage</b>					
No	90	37.5a <sup>a</sup>	1.2d	1.5b	1.4c
	120	37.3a	1.2d	2.2a	1.4c
	150	36.3ab	1.4bc	2.3a	2.0b
Yes	90	33.4ab	1.3cd	1.5b	2.0b
	120	32.6b	1.5b	2.3a	2.1b
	150	31.9b	1.7a	2.3a	2.3a
<b>Ethylene x Ripening</b>					
No	0	55.4a	1.2c	1.8b	1.4c
	7	18.6c	1.4b	2.2a	1.8b
Yes	0	49.7b	1.4b	1.8b	1.9b
	7	15.6cd	1.6a	2.3a	2.3a

<sup>a</sup>Means in a column, within treatments, not followed by a common letter are significantly different ( $P > 0.05$ )

<sup>a</sup>Graded on a scale of 1 to 4 (1 = excellent/none and 4 = poor/severe).

## CONCLUSION

Treatment with ethylene at harvest could compensate for the requirement of cold temperature for induction of ripening in winter, however color, firmness, finish, scald and stem condition change significantly. In addition, holding time of treated pears is also reduced. Considering quality after ripening ethylene-treated, 'Anjou' pears should not be stored more than 90 days in RA and 120 days in CA storage and ethylene-treated 'Bosc' pears should not be stored more than 45 days in RA and 90 days in CA storage.

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